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Affective responses to physical activity in obese women: A high-intensity interval bout vs. a longer isocaloric moderate-intensity bout

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Affective responses to physical activity in obese women: A high-intensity interval bout vs. a longer, isocaloric moderate-intensity bout

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ABSTRACT

BACKGROUND: As the prevalence of obesity and inactivity continue to increase worldwide, the need for effective intervention strategies remains. Despite the well-known benefits of leading a physically active lifestyle, of those individuals classified as obese, only 3.0% of the women and 6.4% of the men trying to lose weight actually meet the 60 min/day physical activity guidelines for weight management (Bish et al., 2005). With lack of time being one of the most oft-cited reasons for not being active (King et al., 2000), the use of short-duration, high-intensity interval training (HIT) has been suggested as a time-efficient means to potentially address this problem (Gibala, 2007). However, the long-term sustainability of the HIT approach in non-athletic populations has not been investigated. Affective responses to bouts of exercise have been linked to exercise adherence (Williams et al., 2008) and, importantly, obese individuals have been found to report lower levels of pleasure in response to exercise than normal-weight and overweight individuals (Ekkekakis et al., in press).

PURPOSE: Thus, the aim of the present study was to compare the affective responses of obese women during a shorter, high-intensity interval session and a longer, isocaloric moderate-intensity session, in order to evaluate the appropriateness and practicality of implementing HIT exercise for this population.

METHODS: Twenty-four obese and inactive women (mean age 39.25 years) first completed an incremental cycle ergometer exercise test to determine their ventilatory threshold (VT). They then completed two experimental exercise conditions that were counterbalanced: 1) a high-intensity interval session (HIT) that involved 4 intervals of cycling at 85% of VT for 2 min and 115% of VT for 3 min for a total of 20 min and 2) an isocaloric, moderate-intensity bout (MOD) that involved cycling at 90% of VT for 25 min. The Feeling Scale was administered before, during, and after exercise. The Physical Activity Enjoyment Scale (PACES) was also administered after the cool-down.

RESULTS: The participants' Feeling Scale and PACES scores were significantly lower (indicating less pleasure and enjoyment, respectively) during the HIT session, than the MOD session.

CONCLUSION: On the basis of affective responses and enjoyment, the HIT protocol used in the current study appears to be even more challenging than the traditional MOD format for obese inactive women. These data may have implications for the practicality and long-term sustainability of HIT training protocols in the domain of public health. In evaluating the appropriateness of the HIT approach for inactive obese women, exercise practitioners should take into consideration the impact of this method on affective responses, as well as its possible implications for adherence.

CHAPTER 1. INTRODUCTION

As the prevalence of obesity continues to increase worldwide, the need for effective intervention strategies remains imperative. While obesity is a multi-faceted condition that is influenced by the interaction of various factors, the focus of the current study will be on the role of physical activity. The root of the problem, from a behavioral perspective, is that, despite the fact that human beings are genetically designed for active lifestyles, they live in societies driven by technology (Eaton & Eaton, 2003), which has resulted in high physical inactivity rates. Additionally, national survey data from 2007 showed that 34.3% of the adult United States population was reported to have a body mass index (BMI) of 30 (kg/m^2) or higher, thus classifying them as obese (Ogden, Carroll, McDowell, & Flegal, 2007). Considering that both obesity and physical inactivity have been linked to numerous health complications as well as premature death (Fogelholm, Kukkonen-Harjula, Nenonen, & Pasanen, 2000; Ogden et al., 2007), it is important to continue exploring means for assisting obese individuals in becoming more active.

This issue is complicated by the daunting amount of physical activity that is recommended in order to achieve effective weight management. While no definitive answer exists, Blair, LaMonte, and Nichaman (2004) reviewed evidence suggesting that, in addition to decreasing caloric intake, daily physical activity for at least 60 min is essential to effectively manage one’s weight. Unfortunately, the Behavioral Risk Factor Surveillance Survey indicated that, of those classified as obese, only 3.0% of the women and 6.4% of the men trying to lose weight actually met these physical activity guidelines (Bish et al., 2005). Clearly, prescribing an overwhelming duration of physical activity is unlikely to be a successful intervention strategy among obese individuals. Additionally, obese individuals have been found to have a lower tolerance for physical activity intensity (Ekkekakis & Lind, 2006), which becomes problematic when trying to determine how to develop time-efficient, yet effective, bouts of physical activity for this population.

One of the most oft-cited reasons for not being active is a lack of time (King et al., 2000), thus making it even more unrealistic for a given individual to obtain at least 60 min of activity on a daily basis. Gibala (2007) proposed the idea of using short-duration, high-intensity interval training (HIT) as a means to potentially address this issue. While there is no universally accepted definition of HIT, Gibala and McGee (2008, p. 58) suggested that "HIT generally refers to repeated sessions of relatively brief intermittent exercise, often performed with an 'all out' effort or at an intensity close to that which elicits VO_{2peak}" (i.e., $\geq$ 90% VO_{2peak}). They went on to state that the high-intensity bouts of HIT can last anywhere "from a few seconds to several minutes" (Gibala & McGee, 2008, p. 58). Gibala (2007) suggested that HIT may provide benefits similar to those obtained through longer-duration, low-intensity physical activity bouts but without the additional time commitment. Recently, researchers have proposed that HIT may actually be more effective than the current recommendations, as findings have shown greater improvements in VO_{2max} (Helgerud et al., 2007), as well as increased capacity to oxidize fat during HIT (Talanian et al., 2007). VO_{2max}, also referred to as maximal oxygen consumption, is the criterion measure of cardiorespiratory fitness (ACSM, 2010). In the study by Helgerud et al. (2007), HIT was found to increase VO_{2max} by 5.5-7.2% over an 8-week period, while participants undergoing either moderate-intensity training at the lactate threshold or low-intensity training showed no improvements in cardiorespiratory fitness. Such findings suggest that the use of HIT could lead to more time-efficient improvements in fitness, as well as accelerated fat oxidation.

In addition to the constraint of time, obesity acts as yet another barrier to being physically active. The idea that physical activity may be too exhausting for obese individuals has been examined recently with findings showing obese individuals to have less positive affective responses to acute bouts of physical activity when compared to both normal-weight and overweight individuals (Ekkekakis, Lind, & Vazou, in press). Affective responses to physical activity have recently been shown to predict future physical activity participation (Williams et al., 2008). Thus, it is necessary to continue exploring the affective responses to physical activity experienced by obese individuals. Such findings could help to determine how to improve their physical activity experience in an effort to increase participation as well as adherence.

However, while the obesity rates continue to increase, it appears that the affective responses of obese individuals to physical activity have received minimal research attention. Despite this lack of research, obtaining more information on this topic could aid this population in becoming and remaining more active. Therefore, the purpose of the current study was to contrast how obese women respond affectively to both a HIT session and a longer, isocaloric, moderate-intensity session. This study evaluated the appropriateness and practicality of implementing HIT exercise sessions for obese individuals. It was hypothesized that women participants would exhibit similar affective responses in the two conditions. This would suggest HIT might indeed provide an effective and time-efficient workout, possibly encouraging improved adherence to physical activity.

CHAPTER 2. LITERATURE REVIEW

Current obesity rates in developed countries appear to be continually rising, with the most recent statistics showing that 34.3% of adults in the United States are considered obese (Ogden et al., 2007). Although numerous factors contribute to obesity, interventions tend to target behavioral aspects, as these are typically more amenable to change (Fogelholm et al., 2000). More specifically, involvement in physical activity is of growing interest as it is often a vital component of both the treatment and the prevention of obesity. Although physical activity has been shown to result in weight loss in obese individuals in at least some studies (Weyer, Linkeschowa, Heise, Giesen, & Spraul, 1998), most obese individuals are insufficiently active (Bish et al., 2005). Interestingly, Pagato, Spring, Cook, McChargue, and Schneider (2006) found women with higher BMI to be less likely to engage in behaviors typically viewed as rewarding. It was found that their "disengagement was related to a diminished subjective enjoyment of those behaviors" (Pagato et al., 2006 pp. 1427-1428). Thus, it seems that the element of enjoyment should be taken into account in designing interventions for obese individuals, if these interventions are to be sustainable in the long run.

As mentioned earlier, bouts of continuous moderate-intensity exercise of 60-90 min or more are recommended for successful weight management and weight loss (ACSM, 2010; Blair et al., 2004; Donnelly et al., 2009; Erlichman, Kerbey, & James, 2002). However, such a daunting amount is unlikely to be achieved by obese individuals. The rationale behind such exercise recommendations is that most individuals find a moderate level of intensity more tolerable and, therefore, this level of intensity is also more likely to lead to higher adherence to an exercise program. However, in order to achieve the high levels of total caloric expenditure necessary to achieve weight loss, exercising at a moderate intensity entails exercising for a long duration. American College of Sports Medicine guidelines (ACSM, 2010) recommend balancing the duration and intensity of exercise bouts in order to maximize the total number of calories expended. Conceivably, this allows for exercise bouts of shorter duration that are performed at a higher intensity. However, how intense is "too intense" and how long is "too long" remain unanswered questions.

Recently, Gibala (2007) proposed that short-duration, high-intensity interval training (HIT) may provide benefits comparable to those of longer-duration, moderate-intensity exercise with the added benefit of time efficiency. If, for example, HIT resulted in accelerated weight loss and greater improvements in fitness, this could have important implications for raising the adherence rates of people who become discouraged when they do not see results early on (Jones, Harris, & Waller, 1998; Jones, Harris, Waller, & Coggins, 2005; Sears & Stanton, 2001), as well as the people who perceive the lack of time as their main barrier (King et al., 2000). Although most data on the effectiveness of HIT have so far referred to fitness improvement in young adults (mainly athletes), Talanian et al. (2007) examined the effect of two weeks of HIT on fat oxidation in healthy, normal-weight women. The HIT protocol consisted of 60-min sessions performed every other day over 2 weeks, alternating between 4-min bouts at ~90% VO_{2peak} and 2-min rest periods. This regimen resulted in increased whole-body fat oxidation during exercise in the group of women who were recreationally active 2-3 days per week. The authors suggested that HIT provides a "short-duration stimulus to improve whole-body fat oxidation and the capacity for skeletal muscle to oxidize fat" (p. 1445). Chilibeck, Bell, Farrar, and Martin, (1998) reported similar findings from their experiment with rats, which compared the impact of continuous, moderate-intensity training with that of high-intensity intermittent interval training on mitochondrial fatty acid oxidation. Additionally, a recent study conducted by Wallman, Plant, Rakimov, and Maiorana (2008) noted a trend toward greater decline in android fat mass in the participants who underwent the high-intensity interval training in their 8-week study, in comparison to those who performed moderate-intensity, continuous bouts of cycling.

Not only have researchers found HIT to cause higher fat oxidation, it has also been demonstrated that HIT results in greater increases in fitness when compared to other training regimens matched for total work output and frequency. Helgerud et al. (2007) compared the effects of four training protocols—all equal for total work output and frequency—on participants' VO_2. The four protocols consisted of: 1) a continuous run at 70% HR_{max} for 45 min, 2) a continuous run at 85% HR_{max} for 24.25 min, 3) 47 repetitions of 15-s intervals at 90-95% HR_{max} with 15-s active rest bouts at 70% HR_{max} for 23.5 min, and 4) 4 repetitions of 4-min bouts at 90-95% HR_{max} with 3-min bouts at 70% HR_{max} for 28 min. The 15-s interval protocol and the 4-min interval protocol resulted in VO_2 improvements of 5.5% and 7.2% respectively, while the other protocols showed no change in VO_2 over the 8-week span of the study. Such findings support Gibala’s (2007) suggestion that HIT offers a time-efficient approach to exercise that may provide comparable benefits to those seen in moderate-intensity, longer-duration exercise bouts.

Considering the benefits that have been linked to HIT, following such an exercise program could provide substantial benefits in a time-efficient manner for a variety of special populations that struggle to adhere to an exercise routine. However, Gibala and McGee (2008) point out that typically their research has used repeated bouts of cycling at all-out intensities for 30-s (Wingate tests) interspersed with 4-min periods of rest. The authors warned that this type of exercise clearly requires high levels of motivation from participants. Furthermore, Gibala and McGee (2008) cautioned about applying the Wingate test in untrained individuals, stating that “given the extreme nature of the exercise, it is doubtful that the general population could safely or practically adopt the model” (Gibala & McGee, 2008, p. 62). They recommend that similar to “the recent work by Talanian et al. (2007), future studies should examine modified interval-based approaches to identify the optimal combination of training intensity and volume necessary to induce adaptations in a practical time-efficient manner” (Gibala & McGee, 2008, p. 62).

Appropriately, Puhan and colleagues (2004) compared the effect of modified HIT to high-intensity, continuous training on various physiological factors in individuals with chronic obstructive pulmonary disease (COPD). Participants were randomly assigned to complete the HIT protocol or high-intensity protocol for 3 weeks (total of 12-15 exercise sessions). The HIT protocol required participants to perform interval exercise that involved alternating between 20-s bouts at 50% of short-term maximum exercise capacity (~90-100% of VO_{2max}) and 40-s bouts at 10% of short-term maximum exercise capacity for a total of 20 min. High-intensity, continuous exercise sessions consisted of cycling for 20 min at 70% or more of short-term maximum exercise capacity. The researchers found rehabilitation patients who participated in HIT to have similar improvements in Chronic Respiratory Questionnaire (CRQ) scores to those who did high-intensity, continuous exercise over the 3-week period. Additionally, participants who performed the HIT sessions had greater exercise tolerance, as evidenced by the fewer breaks that were taken during exercise sessions. Additionally, other studies have found various HIT exercise protocols to have similar effects on COPD patients when compared to moderate, continuous exercise (Arnardóttir, Boman, Larsson, Hedenström, & Emtner, 2007; Varga et al., 2007; Vogiatzis, Nanas, & Roussos, 2002).

Investigators have also examined the effectiveness of applying HIT in cardiac rehabilitation programs. A recent study by Wisløff and colleagues (2007) involved randomly assigning post-infarction chronic heart failure (CHF) patients to interval training (AIT), moderate, continuous training (MCT), or a control group for 12 weeks. The AIT protocol entailed a10-min warm-up at 50-60% HR_{peak} before performing four intervals of “uphill” treadmill walking (4-min bouts at 90-95% HR_{peak} interspersed with 3-min bouts at 50-70% HR_{peak} for a total exercise time of 38 min). Those in the MCT group walked continuously at 70-75% HR_{peak} for 47 min to achieve an equivalent caloric expenditure between the two conditions. Both groups performed their training programs 3 times per week, with 2 sessions being supervised and 1 performed at home. The control group attended supervised training sessions once every 3 weeks. At the 12-week follow-up, the AIT group showed greater improvements in VO_{2peak}, anaerobic threshold, work economy, quality of life and various measures of left ventricle functioning than both the control and the MCT conditions. Other researchers have also found interval training to have greater or comparable benefits to moderate continuous training programs in individuals with coronary artery disease, CHF, or following bypass surgery (Meyer, Lehmann, Sunder, Keul, & Weidemann, 1990; Meyer et al., 1998; Warburton et al., 2005).

An important variable that has been linked to adherence, yet is often overlooked when exercise recommendations are made, is how people feel during exercise bouts. When trying to determine the appropriate intensity and duration to use during the application of HIT in obese individuals, it is necessary to take into account that whether or not they perceive the exercise to be pleasurable will likely predict the amount of physical activity that they undertake in the future.

Although these suggestions seem promising in other populations, applying them to obese individuals is complicated by numerous factors. First, obese individuals have been found to show decreased tolerance for exercise intensity. Obese participants were found to use an average of 56% of their VO_{2max} compared to only 36% by the normal-weight women at paces that were self-selected (Mattsson, Larsson, & Rossner, 1997). Ekkekakis and Lind (2006) also reported overall higher levels of exertion in overweight women compared to those reported by normal-weight individuals. Thus, using high-intensity exercise with obese individuals may result in less positive affective responses and, in turn, these may have a negative impact on adherence. Therefore, it would be interesting to examine the affective responses of obese individuals to a HIT stimulus.

Secondly, overweight and obese women appear to have a preference for lower intensity exercise. In the study by Mattsson and colleagues (1997), obese women were found to self-select slower walking paces than those chosen by their normal-weight counterparts. Additionally, when allowed to choose between altering the intensity or the duration of their exercise bout, overweight and obese participants were willing to walk longer if it meant that they could decrease the intensity at which they walked (Fogelholm et al., 2000). These findings provide support for the position that obese individuals may be more sensitive to exercise intensity than their normal-weight counterparts. Therefore, finding a way to structure exercise bouts to be more tolerable and time-efficient yet also effective for obese individuals poses a considerable challenge for researchers and practitioners alike.

Perhaps not surprisingly, obese individuals have been reported to be less likely to meet longer-duration exercise recommendations (Weyer et al., 1998). Thus, it is necessary to explore the alternative of providing them with a more time-efficient option. Weyer and colleagues (1998) assessed the physical activity habits of obese men and women who were following a dietary treatment plan. They found that 34% of participants accumulated 30-min bouts of exercise (Pate et al., 1995) compared with only 17% of participants accumulating 20 to 60-min bouts. As mentioned earlier, of obese men and women who reported trying to lose weight, only 6.4% and 3.0%, respectively, were found to meet the daily 60-90 min/day physical activity recommendations (Bish et al., 2005).

An important aspect of the exercise experience, yet one that remains almost completely unexplored, are the affective responses of obese individuals to exercise bouts of different characteristics. In regard to normal-weight individuals, Ekkekakis, Hall, and Petruzzello (2005) predicted that more positive affective responses would tend to occur during moderate-intensity exercise (below ventilatory threshold, or VT), whereas more negative affective responses would occur at higher exercise intensities, specifically those beyond the VT. Additionally, these authors predicted that exercise bouts performed at intensities proximal to the VT would show variability in affective responses, with some participants reporting increases and others decreases in pleasure. However, it is not known whether the affective responses of obese individuals during exercise would mirror those of their normal-weight counterparts. Given the role of affect in adherence (Williams et al., 2008), which is becoming increasingly clear, gaining a better understanding of the affective responses of obese individuals to exercise bouts could prove beneficial.

Ekkekakis and Lind (2006) showed that imposing an intensity level of just 10% higher than that self-selected by participants in an earlier trial resulted in significantly less positive affective responses throughout the exercise bout for overweight individuals. This is likely due to the fact that overweight participants were found to use a higher percentage of both their peak heart rate as well as their VO_{2peak} compared to normal-weight individuals during the self-selected intensity condition, as well as when the intensity was imposed. Consider the implications of a personal trainer who is trying to speed the weight-loss results for an obese client. If he or she were to impose an intensity just slightly above what the client might have self-selected, this could in turn cause the client to experience less positive affect, which, if repeated over several bouts, could result in decreased adherence or dropout from the exercise plan, as suggested by the work of Williams et al., (2008).

Additionally, obese, sedentary women have been found to report less positive affective responses to exercise in comparison to normal-weight and overweight participants (Ekkekakis et al., in press). Such findings are of critical importance as individuals' affective responses during exercise have been shown to predict self-reported physical activity 6 and 12 months later (Williams et al., 2008). More specifically, Williams et al., (2008) found that sedentary adults who reported more positive affect in response to a single, moderate-intensity bout of exercise also reported participation in more min of physical activity at 6- and 12-month follow-ups. Likewise, more positive exercise-related affective associations (i.e., whether exercise had registered in memory as something pleasant) were related to higher levels of reported physical activity in a study done by Kiviniemi, Voss-Humke, and Seifert (2007). These results suggest that obese individuals' lower adherence rates to physical activity may, at least in part, be due to the less positive affective responses they experience during exercise.

Ekkekakis, Hall, and Petruzzello (2004) suggested that affective responses to exercise may be viewed as a practical guide for prescribing exercise intensity. Currently, recommendations for determining exercise intensity are based on percentages of maximal heart rate (HR_{max}) or VO_2 reserve (ACSM, 2010). Using such methods requires that a person either tracks his or her heart rate during exercise, which is likely to be inaccurate when done by an inexperienced individual, or undergo a submaximal or maximal exercise test to determine maximal exercise capacity, which is very costly and strenuous. Interestingly, the ACSM's (2010) most recent exercise guidelines recommend using affective valence (i.e., Feeling Scale responses) as an "adjunct [measure] of exercise intensity" and state that "further research is needed before [it] can be recommended as [a] primary [tool] for the estimation of exercise intensity" (p. 157). As mentioned earlier, individuals tend to report stable and positive affect when performing exercise below the VT. Importantly, this level of intensity has been found to result in improvements in health (Haskell et al., 2007). Thus, it has been argued that "affective response may be useful as a proxy for VT on which to base prescriptions that are potentially more sustainable and beneficial than traditional prescriptions" (Williams et al., 2008, p. 240).

Accordingly, the aim of the present study was to compare the affective responses of obese women during a shorter, high-intensity interval session and a longer, isocaloric moderate-intensity session. It is hypothesized that women participants will have comparable affective responses in the two conditions, suggesting that HIT may provide a more effective and time-efficient workout, possibly encouraging improved adherence to a physical activity regimen. Determining if the more time-efficient high-intensity interval bout yields more or less positive affective responses may have implications for the appropriateness of prescribing this type of activity to obese individuals.

CHAPTER 3. METHODS

Participants

Participants were 24 women between the ages of 18 and 54 years with a BMI of 30 kg/m^2 or higher. The sample size of 24 was determined based on power analysis calculations using an effect size of d=0.6 for a within-subject comparison between means (based on a previous study by Ekkekakis et al., in press), a desired power level of 0.8, and an alpha of 0.05. The participants were recruited via e-mails sent throughout a large university in the Midwestern United States and fliers that were (a) posted throughout the community and campus, (b) distributed at local super-markets, and (c) inserted into the local newspaper. In total, it is estimated that over 8,000 fliers were posted during recruitment efforts.

Initial inquires to participate in the study were received from 488 women who had seen fliers, received an e-mail advertisement, or heard about the study via word of mouth. Criteria for exclusion included smoking, hypertension, dyslipidemia, impaired fasting glucose, taking medication that could impact cardiovascular or metabolic responses to exercise, and being 55 years of age and older. The inclusion criteria were that the women (a) participated in less than 30 min of moderate physical activity per day on most days of the week within the past 6 months, based on their responses to the 7-day physical activity recall interview (Appendix A; Blair et al., 1985); (b) had a physical examination in the previous 12 months that revealed no contraindications to vigorous physical activity; (c) gave negative responses to all questions on the Physical Activity Readiness Questionnaire (PAR-Q; Appendix A; Thomas, Reading, & Shephard, 1992) and were, thus, apparently healthy; and (d) were not suffering from any injuries or ailments at the time. Of the 488 women who initially expressed interest, 39 met the eligibility criteria, and, of those, 7 women did not attend or schedule their first session and 1 had a change in health status prior to coming into the laboratory that prevented her from participating. Of the 31 individuals that were enrolled into the study, 7 dropped out as a result of the following: injury unrelated to the study (n=2), claustrophobia with the mask (n=2), personal reasons (n=1), and being unable to complete the HIT bout (n=1). Thus, the results that are reported here are based on 24 women who participated in all three sessions.

The demographic and anthropometric data for these 24 participants are presented in Table 1. The participants ranged in age from 19 to 53 years, with a mean age of 39.25±11.23 years. The mean body fat percentage was 44.0%±4.27% and the mean BMI was 34.96±4.46 kg/m^2. The average VO_{2peak} was 19.05±3.67 ml·kg·min^{-1}, which places this group below the 1st percentile or the 'very poor' classification for cardiorespiratory fitness according to the most recent ACSM (2010) standards.

Table 1. Descriptive statistics (Means ± SD) for demographic and physiological data.

	Mean ± SD
Age (years)	39.25±11.23
Height (cm)	164.15±7.19
Body mass (kg)	94.20±12.81
Body fat (%)	44.0±4.27
Body mass index (kg/m^2)	34.96±4.46
VO_{2peak} (l/min)	1.77±0.31
VO_{2peak} (ml·kg·min^{-1})	19.05±3.67

Measures

BMI was calculated from body stature and mass measurements. Body mass was measured with a Bioelectrical Impedance scale (model BF-626, Tanita, Tokyo, Japan) according to standard instructions. Stature was measured with a standard wall-mounted stadiometer.

Heart rate was assessed with a telemetric heart rate monitor (Polar Electro Oy, Kempele, Finland), consisting of a stretchable chest band and a radio transmitter interfaced to a computerized metabolic analysis system (see below). Validation studies have shown correlations between this method and heart rate measured by electrocardiography typically greater than .90, with differences of less than ±5 beats/min across most of the exercise intensity range (Terbizan, Dolezal, & Albano, 2002).

Oxygen uptake (VO_2) was assessed with an open-circuit computerized spirometry system (model TrueOne 2400, ParvoMedics, Salt Lake City, UT, USA). Before each test, this system was calibrated for oxygen and carbon dioxide using a certified mixture of these two gases and for ventilation using a 3-l syringe and a software-guided 15-stroke calibration procedure. A validation study of this system found that the differences compared to the gold-standard Douglas bag method were "so small as to be not physiologically significant" (Bassett et al., 2001). Caloric expenditure during exercise as well as post-exercise was computed by the metabolic cart using the Weir equation of caloric expenditure = 5.616 x VO_2 ml/min + 1.584 x VCO_2 ml/min (Weir, 1949).

The affective dimension of pleasure–displeasure during exercise was assessed with the Feeling Scale (FS; Appendix B; Hardy & Rejeski, 1989). The FS is an 11-point, single-item, bipolar rating scale commonly used for the assessment of affective responses during exercise. The scale ranges from -5 to +5. Anchors are provided at zero ('Neutral') and at all odd integers, ranging from 'Very Good' (+5) to 'Very Bad' (-5). Hall and colleagues (2002) have provided evidence of significant correlations between the FS and other self-report measures of pleasure, stating that:

> In previous work in our laboratory, the FS has exhibited correlations ranging from .51 to .88 with the valence scale of the Self Assessment Manikin (Lang, 1980) and from .41 to .59 with the valence scale of the Affect Grid (Russell, Weiss, & Mendelsohn, 1989). (p. 54-55).

The Felt Arousal Scale (FAS; Appendix B; Svebak, & Murgatroyd, 1985) was used to assess participants' level of activation. The FAS is a six-point rating scale ranging from 1 to 6, with anchors at 1 ('Low Arousal') and 6 ('High Arousal').

The Rating of Perceived Exertion (RPE; Appendix B; Borg, 1998) was used as a measure of perceived effort during exercise. The RPE is a 15-point scale ranging from 6 to 20, with anchors ranging from "No exertion at all" to "Maximal exertion." A meta-analysis of validity data has shown that the RPE exhibits the following weighted mean validity coefficients with physiological indices of intensity: 0.62 for heart rate, 0.57 for blood lactate, 0.64 for percentage of maximal aerobic capacity, 0.63 for oxygen consumption, 0.61 for ventilation, and 0.72 for respiratory rate (Chen, Fan, & Moe, 2002).

The Physical Activity Enjoyment Scale was also administered to measure participants' sense of post-exercise enjoyment (PACES; Appendix B; Kendzierski & DeCarlo, 1991).

Procedures

Participants underwent 3 exercise sessions on a recumbent cycle ergometer (Corival Recumbent, Lode BV, Groningen, Netherlands), which included an incremental test to volitional fatigue, a HIT session and a moderate-intensity session (the latter two performed in counter-balanced order). Pilot testing was preformed to determine the necessary intensities and durations that would result in similar caloric expenditure from the two experimental sessions. A brief familiarization period was included during the first portion of the incremental-test session to make participants feel comfortable in the laboratory environment and to give them a chance to ask questions. Additionally, all participants read and signed an informed consent document (Appendix C) during this familiarization period.

At the beginning of each exercise session, the participants were fitted with a nasal and mouth breathing face mask (model 8920/30, Hans Rudolph, Kansas City, MO, USA) equipped with an ultralow-resistance, T-shaped, two-way, nonrebreathing valve (model 2700, Hans Rudolph), which was then connected to the spirometry system via plastic tubing (3.5 cm in diameter). A gel sealant (model 7701, Hans Rudolph) was applied to the face mask, when necessary, to prevent leaks. Two min of resting data were recorded while the participants were seated on the cycle ergometer, to make certain the metabolic system was operating properly.

The incremental cycle ergometer test was performed during the initial visit, to determine the participants' VT and peak oxygen consumption. Participants began cycling against an initial workload of 20W for 3 min, followed by 10W increases during each subsequent min of the test. This was continued until each participant reached the point of volitional exhaustion. The highest 60-s average value of oxygen uptake was designated VO_{2peak} and the highest 60-s average value of heart rate was designated HR_{peak}. Criteria for achieving peak exercise capacity during the incremental test included reaching age-predicted maximal heart rate, a plateau in oxygen consumption with increasing workloads, and a respiratory exchange ratio (RER) greater than 1.1.

For the HIT session, the participants alternated between 3-min segments at 115% of their VT and 2-min segments at 85% of their VT (active recovery). This cycle was repeated four times to accumulate 20 min. The intensities were based around VT as opposed to VO_{2peak} to reduce the probability of having some participants performing exercise above their VT while others performed exercise below their VT. Setting the low intensity below VT (85%) during the active recovery portions was intended to allow a positive rebound of the affective state as well as physiological recovery following each high-intensity portion (Ekkekakis et al., 2005). The high intensity was set at 115% of VT in order to elicit increased HR and VO_2 responses while being tolerable (i.e., without causing large declines in the participants' affective state). In general, the duration of the high-intensity portion was longer and the intensity was lower than what has been used in studies with trained and fit participants (Gibala & McGee, 2008) in order to increase the safety of the protocol and to accommodate the decreased tolerance for high-intensity exercise that has been found for obese individuals (Mattsson et al., 1997). Overall, the current study's HIT protocol is comparable to what other researchers have recently used with obese women (e.g., 2-min alternations between low-intensity periods at 80% of VT and high-intensity periods of 120% of VT; Coquart et al., 2008). The FS, FAS, and RPE were administered in a randomized order at the end of each high-intensity and active-recovery period (a total of 8 times, at min 2, 5, 7, 10, 12, 15, 17, 20).

The moderate-intensity bout (MOD) required participants to exercise continuously for 25 min at 90% of their VT. This combination of intensity and duration was chosen to provide participants with a comparable amount of total work to that used in their HIT session (Coquart et al., 2008). Furthermore, setting the intensity just below the VT was intended to allow participants to maintain a relative physiological steady-state for the duration of the bout. The FS, FAS, and RPE were administered in a randomized order every 2.5 min during this session (a total of 10 times, at min 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, 20.0, 22.5, 25.0).

In order to compare the participants' responses at equivalent time points (despite the different durations of the HIT and MOD bouts) segmented quadratic regressions were calculated using the measured responses at the 10 time points of the MOD bout. This involved dividing the 10 data points in half, fitting a 2^{nd} degree polynomial regression to each segment, and estimating values at 4 time points in order to have comparisons at the following percentages of the total duration for each session: 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100%.

Additionally, the FS and FAS were administered at baseline, immediately prior to the exercise bout, immediately after the exercise bout, post cool-down, and 10, 20, and 30 min after exercise for both the HIT and the MOD conditions. The PACES was also administered post cool-down in both conditions.

Determination of the Ventilatory Threshold

The ventilatory threshold was identified offline using a computerized version of the three-method combined procedure suggested by Gaskill et al., (2001). The first of these methods involves the examination of the so-called V-slope, which requires identifying a breakpoint in the slope of the graphical representation of CO_2 production over O_2 utilization. The second method was the method of the ventilatory equivalents. This entails plotting the ventilatory equivalents for O_2 (V_E/VO_2) and CO_2 (V_E/VCO_2) over time or over O_2 utilization, and identifying the exercise intensity corresponding to the first rise in V_E/VO_2 that occurs without a concurrent rise in V_E/VCO_2. Lastly, the excess CO_2 method was employed, which involved plotting excess CO_2 production over time or O_2 utilization and identifying the exercise intensity corresponding to an increase in excess CO_2 from steady state. All data were converted to 20-s averages before analysis. The ventilatory threshold was determined to occur at the point where at least two of the three methods converged or the point that resulted in the lowest mean square residual. These criteria were followed by three investigators who analyzed the data independently. The final determination of each participant's VT required agreement between at least 2 of the 3 investigators.

Analyses

A 2 (Trial) x 9 (Time) repeated-measures analysis of variance (ANOVA) was used for the FS data collected during exercise. Additionally, a 2 (Trial) x 7 (Time) ANOVA was used to analyze the FS responses pre-to-post-exercise. RPE, VO_2, and HR were each analyzed with a 2 (Trial) x 8 (Time) ANOVA of the total exercise duration. Since the sphericity assumption is typically violated in analyses involving multiple repeated measures, the Greenhouse-Geisser was used to adjust the degrees of freedom. When significant interactions were found, a repeated measures ANOVA within each condition was run, followed by Bonferroni-corrected pairwise comparisons, to determine where the significant differences lied.

CHAPTER 4. RESULTS

Manipulation checks

Heart rate. A 2 (Trial) by 9 (Time) repeated-measures ANOVA on heart rate showed a significant main effect for time, $F(2.09, 47.9) = 309.53$, $P< 0.001$, $\eta^2 = .93$, as well as trial, $F(1, 23) = 36.12$, $P< 0.001$, $\eta^2 = .61$. A significant interaction between time and trial was also found, as illustrated in Figure 1, $F(2.52, 50.04) = 51.42$, $P< 0.001$, $\eta^2 = .69$, which demonstrates that HR was significantly higher in the HIT condition than in the MOD condition. The ANOVA included measurements at rest, and 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100% of the total exercise duration. Mean HR was 124.85 bpm during the active recovery portion of the HIT session and 148.17 bpm during the high-intensity portion. During the MOD session, HR averaged 125.67 bpm over 25 min.

VO_2. On average, participants' VT occurred at 61.57% of their VO_{2peak}. For the 2 (Trial) by 8 (Time) repeated-measures ANOVA on VO_2 during exercise, a main effect of time was found, $F(3.5, 80.52) = 47.36$, $P< 0.001$, $\eta^2 =.67$, as well as a trial main effect, $F(3.93, 23) = 44.63$, $P< 0.001$, $\eta^2 = .66$. A significant interaction was also found, as illustrated in Figure 2, $F(3.04, 69.8) = 38.37$, $P< 0.001$, $\eta^2 = .63$, which showed VO_2 to be significantly higher in the HIT condition than in the MOD condition. The ANOVA included measurements of VO_2 at 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100% of the exercise duration. Figure 2 illustrates the oscillation of VO_2 during the HIT trial as well as the relatively stable VO_2 during the MOD session. On average, participants oscillated between 65% and 90% of their VO_{2max} in the HIT bout during the active recovery and high-intensity segments, respectively. For the MOD session, participants achieved 66% of their VO_{2max} on average. The mean percentage of VT that participants were at during the HIT session oscillated between 147 and 105%. During the MOD session, participants worked at an average of 108% of VT.

Caloric expenditure. A paired t-test revealed no difference between caloric expenditure in the HIT (*M*=197.17 kcals) and MOD (*M*=202.58 kcals) sessions, with mean expenditure from the two sessions at 199.07 calories and a mean difference of 5.42 ± 20.03 calories, t= -1.33, P = 0.198, d= -0.22.

Self-reported responses

RPE. A 2 (Trial) by 8 (Time) repeated-measures ANOVA on RPE showed a time main effect, $F(3.32, 76.37) = 71.34$, $P< 0.001$, $\eta^2 = .76$, and a trial main effect, $F(1, 23) = 6.24$, $P< 0.001$, $\eta^2 = .21$ (Table 5). A significant interaction between time and trial, $F(3.4, 78.05) = 34.25$, $P< 0.001$ $\eta^2 = .60$ also occurred. The ANOVA included administration of RPE at 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100% of the exercise duration, and showed RPE to be significantly higher in the HIT session than the MOD session. The results of the post-hoc tests between the two conditions showed RPE to be significantly different at 10%, 25%, 50%, 75%, and 100% of exercise duration (Table 2). Post-hoc analysis results within each condition are shown in Table 3. Figure 3 illustrates the overall differences in RPE in the HIT and MOD trials.

FS. A paired t-test revealed no significant difference between FS scores before and after participants were fitted with the mask in the HIT, t= 1.45, P = .16, and the MOD sessions, t= 1.16, P = .26. Additionally, baseline FS did not vary from the HIT session to the MOD session prior to fitting participants with the mask (t= .13, P = .90) or after participants were fitted with the mask (t= .16, P = .87). A 2 (Trial) by 9 (Time) repeated-measures ANOVA on FS during exercise showed a time main effect, $F(2.66, 61.11) = 34.92$, $P< 0.001$,

η^2 = .60, as well as a trial main effect, $F(1, 23) = 14.42$, $P < 0.05$, η^2 = .39. A significant interaction between time and trial, $F(3.29, 75.68) = 8.48$, $P < 0.001$, η^2 = .27, was also demonstrated. The ANOVA included administration of the FS at the following time points: immediately prior to the exercise bout, and 10%, 25%, 35%, 50%, 60%, 75%, 85%, and 100% of the total exercise duration. Overall, FS was found to be significantly lower in the HIT session than the MOD session (Figure 4). Results of the post-hoc tests between conditions showed FS to be significantly different at 25%, 50%, 75%, and 100% of exercise duration (Table 4). Post-hoc analyses within each condition are shown in Table 5.

A 2 (Trial) by 7 (Time) ANOVA of FS prior to exercise and post-exercise showed a time main effect $F(2.47, 56.78) = 22.80$, $P < 0.001$, η^2 = .50 but no trial main effect, $F(2, 23)$ = .45, P = .51, η^2 = .02. A significant interaction was found between time and trial, $F(3.07, 70.58) = 4.35$, $P < 0.05$, η^2 = .16. This included administration of the FS immediately prior to the exercise bout, immediately after the exercise bout, post cool-down, and 10, 20, and 30 min after exercise. The results of the post-hoc tests within conditions are shown in Table 6.

FAS. A 2 (Trial) by 9 (Time) repeated-measures ANOVA on FAS showed a time main effect, $F(1.59, 36.51) = 3.56$, $P < 0.05$, η^2 = .13 and a trial main effect, $F(1, 23) = 4.61$, $P < 0.05$, η^2 = .17. No significant interaction was found, although a trend toward significance was demonstrated, $F(3.07,70.68) = 2.60$, $P = 0.06$, η^2 =.10. A 2 (Trial) by 7 (Time) repeated-measures ANOVA on FAS prior to exercise and post-exercise showed a significant time main effect, $F(2.50, 57.58) = 9.87$, $P < 0.001$, η^2 = .30, but did not show a significant trial main effect, $F(1, 23)$ = .32, P = .32, η^2 = .04, or interaction, $F(3.15, 72.53) = 1.63$, P = .19, η^2 = .07.

PACES. A paired *t*-test of the PACES scores showed a significant difference between the levels of enjoyment of the HIT and MOD sessions, $t= -2.14$, $P< 0.05$, $d= -.38$, with higher scores in the MOD trial (mean difference = 8.54 ± 19.54). The mean enjoyment score for the MOD session was 90.79 and the mean enjoyment for the HIT session was 82.25.

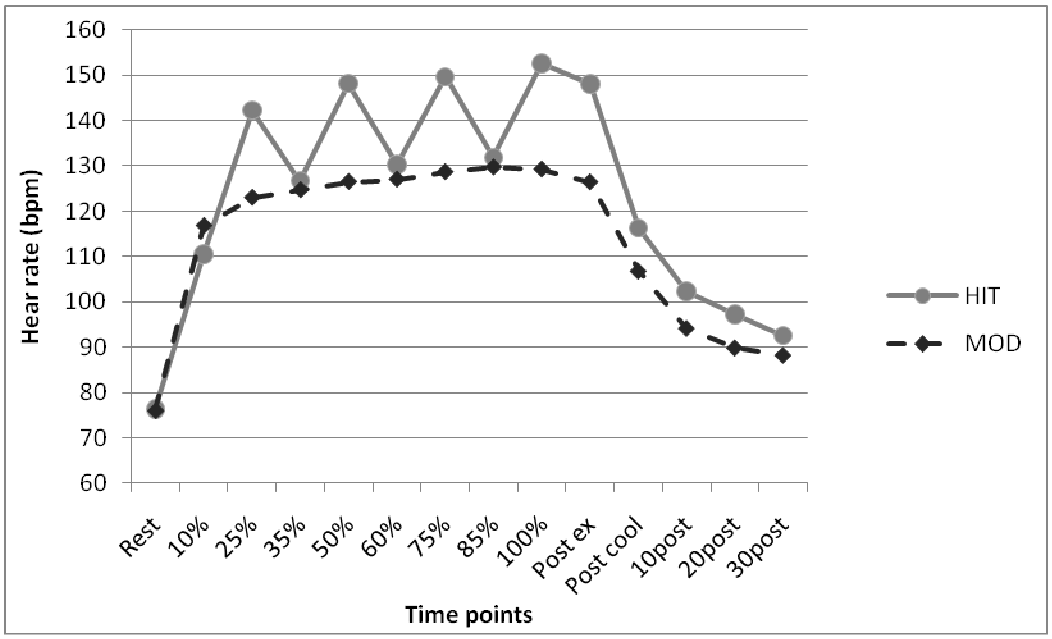

Figure 1. Mean HR responses over time during the HIT and MOD sessions. Time points represent a percentage of the total duration of the exercise sessions as well as the post-exercise measurements.

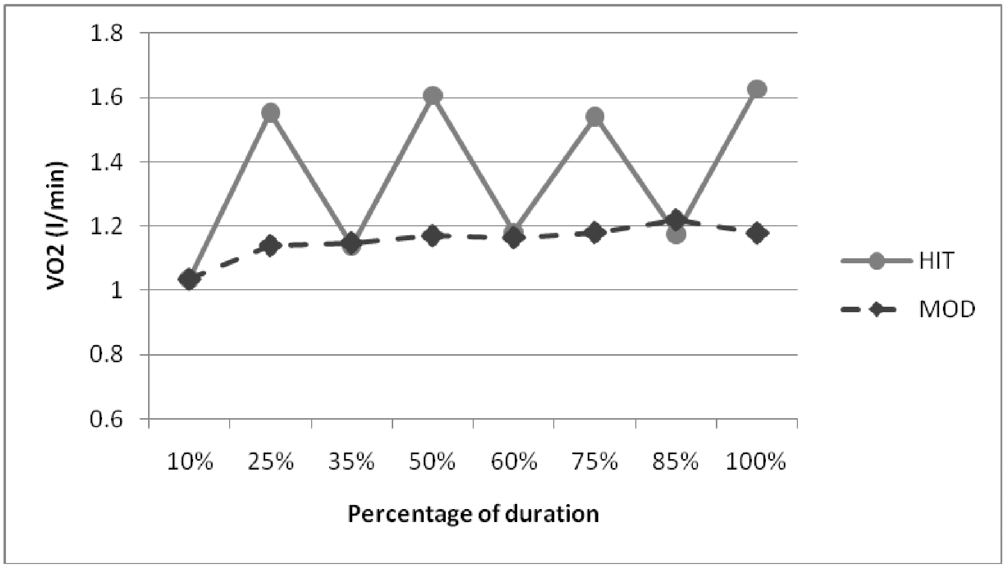

Figure 2. Mean VO_2 over time during the HIT and MOD sessions. Time points represent a percentage of the total duration of the exercise sessions.

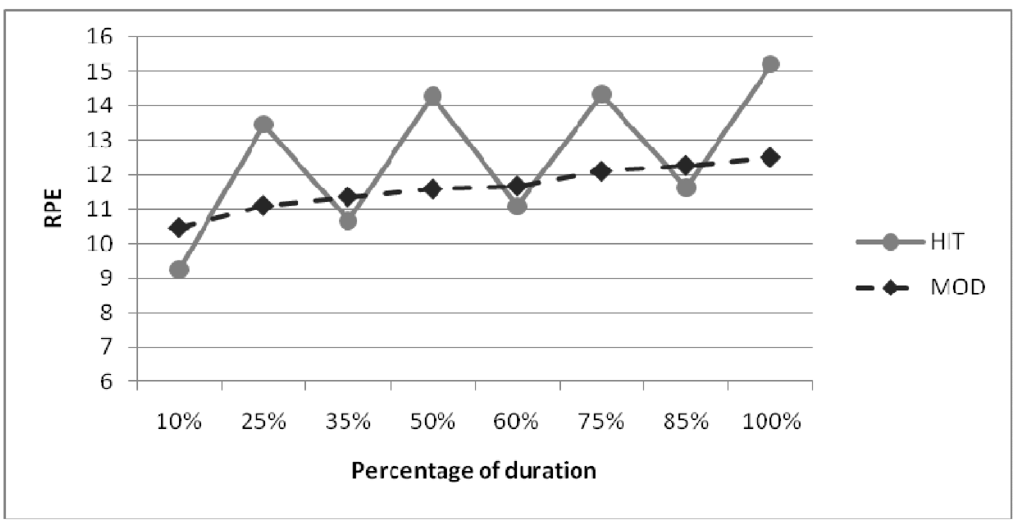

Figure 3. Mean RPE response plotted over time during the HIT and MOD sessions. Time points represent a percentage of the total duration of the exercise sessions.

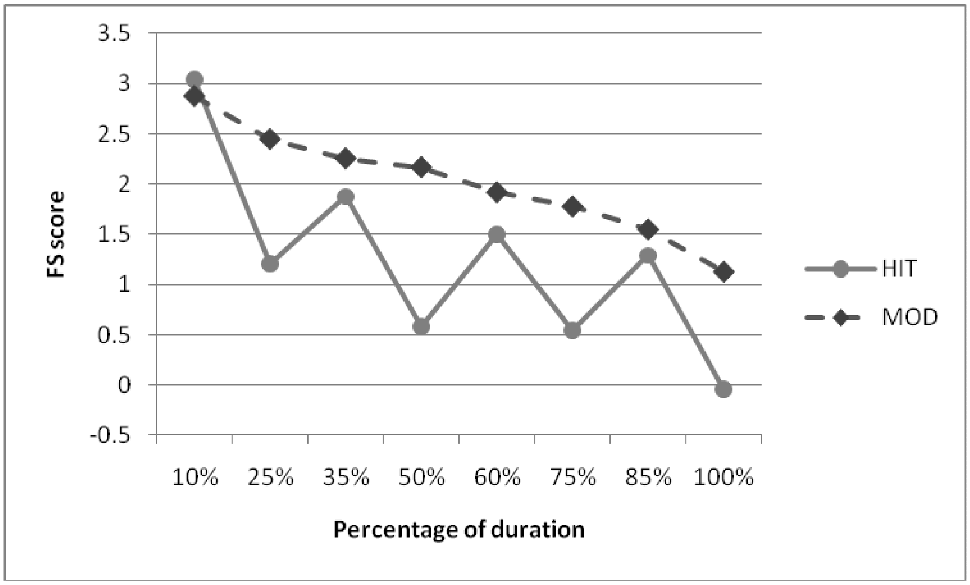

Figure 4. Mean FS response plotted over time during the HIT and MOD sessions. Time points represent a percentage of the total duration of the exercise sessions.

Table 2. Means ± SD and effect sizes *d* with Bonferroni-corrected pairwise comparisons for Rating of Perceived Exertion scale (RPE) scores during exercise in each of the two experimental conditions. Time points represent a percentage of the total duration of the exercise sessions.

Time point	**HIT**	**MOD**	**Effect size**
10 %	9.25±1.87	10.46±1.72	-0.66*
25%	13.46±1.77	11.1±1.50	1.41**
35%	10.67±2.04	11.36±1.56	-0.38
50%	14.29±2.05	11.58±1.84	1.37**
60%	11.08±2.32	11.67±2.24	-0.25
75%	14.33±1.86	12.1±1.89	1.17**
85%	11.63±2.18	12.27±1.91	-0.31
100%	15.21±1.79	12.50±2.0	1.40**

Note: *$P < 0.006$ and ** $P < 0.001$

Table 3. Effects sizes *d* and results of Bonferroni-corrected pairwise comparisons for RPE scores during exercise in the two experimental conditions. The results for the MOD session appear below and the results for the HIT session appear above the main diagonal. Time points represent a percentage of the total duration of the exercise sessions.

Time point	10%	25%	35%	50%	60%	75%	85%	100%
10%	-	-2.27*	-0.71*	-2.52*	-0.86*	-2.68*	-1.15*	-3.25*
25%	-0.39*	-	1.44*	-0.43	1.13*	-0.48	0.91*	-0.97*
35%	-0.54*	-0.17*	-	-1.74*	-0.19	-1.85*	-0.45*	-2.33*
50%	-0.62*	-0.28	-0.13	-	1.44*	-0.02	1.24*	-0.47*
60%	-0.60*	-0.29	-0.16	-0.04	-	-1.52*	-0.24	-1.96*
75%	-0.89*	-0.58*	-0.42	-0.27	-0.21	-	1.31*	-0.47*
85%	-0.98*	-0.67*	-0.51*	-0.36	-0.28	-0.09	-	-1.76*
100%	-1.08*	-0.78*	-0.63*	-0.47*	-0.39	-0.20	-0.12	-

Note: *$P < 0.0018$

Table 4. Means ± SD and effect sizes *d* with Bonferroni-corrected pairwise comparisons for Feeling Scale (FS) ratings during exercise in each of the two experimental conditions. Time points represent a percentage of the total duration of the exercise sessions.

Time point	**HIT**	**MOD**	**Effect size**
Postmask	3.25 ±1.39	3.21 ±1.53	0.03
10 %	3.04 ±1.37	2.88 ±1.57	0.11
25%	1.21 ±1.72	2.45 ±1.39	-0.78*
35%	1.88 ±1.54	2.25 ±1.40	-0.25
50%	0.58 ±1.93	2.17 ±1.31	-0.95*
60%	1.50 ±1.35	1.92 ±1.50	-0.29
75%	0.54 ±1.89	1.78 ±1.25	-0.76*
85%	1.29 ±1.65	1.55 ±1.21	-0.18
100%	-0.04 ±1.94	1.13 ±1.33	-0.69*

Note: * $P < 0.0055$

Table 5. Effects sizes *d* and results of Bonferroni-corrected pairwise comparisons for FS ratings during exercise in the two experimental conditions. The results for the MOD session appear below and the results for the HIT session appear above the main diagonal. Time points represent a percentage of the total duration of the exercise sessions.

	Postmask	10%	25%	35%	50%	60%	75%	85%	100%
Postmask	-	0.15	1.28*	0.92*	1.56*	1.26*	1.61*	1.26*	1.92*
10 %	0.21	-	1.16*	0.79*	1.45*	1.12*	1.49*	1.13*	1.81*
25%	0.51	0.28	-	-0.40	0.34*	-0.19	0.36	-0.05	0.67*
35%	0.64	0.41	0.14	-	0.73*	0.25	0.76*	0.36	1.07*
50%	0.72	0.48	0.20	0.06	-	-0.54*	0.02	-0.39	0.32
60%	0.84*	0.61	0.36	0.23	0.17	-	0.57*	0.14	0.91*
75%	1.01*	0.76*	0.50*	0.36	0.30	0.10	-	-0.42	0.30
85%	1.18*	0.93*	0.68*	0.53*	0.48	0.27	0.18*	-	0.73*
100%	1.43*	1.18*	0.95*	0.81*	0.78*	0.56*	0.50*	0.33*	-

Note: *$P < 0.0014$

Table 6. Effects sizes *d* and results of Bonferroni-corrected pairwise comparisons for FS ratings pre and post-exercise in the two experimental conditions. The results for the MOD session appear below and the results for the HIT session appear above the main diagonal.

Time point	Premask	Postmask	Post ex	Post cool	10 min post	20 min post	30 min post
Premask	-	0.12	1.50*	0.75*	0.24	0.07	-0.03
Postmask	0.11	-	1.40*	0.63	0.10	-0.07	-0.17
Post ex	0.83*	0.75*	-	-0.83*	-1.43*	-1.53*	-1.62*
Post cool	0.61	0.51	-0.31	-	-0.61	-0.75*	-0.85*
10 min post	0.17	0.06	-0.74*	-0.49	-	-0.19	-0.31
20 min post	0.22	0.11	-0.67	-0.41	0.06	-	-0.11
30 min post	0.08	-0.03	-0.80*	-0.56*	-0.09	-0.14	-

Note: *$P < 0.002$

CHAPTER 5. DISCUSSION

The overall purpose of this study was to compare the affective responses of sedentary, obese women during a HIT bout of exercise to those during a MOD bout of exercise, in order to determine the appropriateness of implementing HIT exercise sessions for obese individuals. Taking into account the high rates of inactivity in obese women and the potential benefits of HIT in terms of time-efficiency, it is essential to determine the practicality of using this type of exercise regimen to improve exercise adherence in this population.

Considering that HIT is promoted as a more time-efficient approach in comparison to continuous, moderate-intensity exercise, it is important to recognize that the HIT protocol used in the current study only afforded a time-savings of 5 min. This protocol was designed in an attempt to provide an appropriate combination of interval intensities and durations that would be tolerable for obese individuals. However, implementing HIT for obese individuals is challenging since it is necessary to stick to the principles of HIT (i.e. high-intensity stimulus) while providing an exercise bout that will not be overly exhausting. Additionally, due to the low cardiorespiratory fitness levels found in obese individuals, there is a small range of intensities that are feasible for this population.

Analyses of the HR and VO_2 data showed values to be significantly lower in the MOD condition in comparison to those in the HIT condition. This illustrates that the workloads used in the current study were effective at eliciting the appropriate physiological responses during the two experimental conditions. Furthermore, the caloric expenditure of the two sessions was not significantly different from one another which demonstrates that the protocols were effective in eliciting similar energy expenditure.

The main finding of this study was that FS scores were significantly different in the two exercise sessions, with the overall FS scores in the HIT bout being significantly less positive than those in the MOD bout (Figure 4). These findings do not support the hypothesis for the current study, according to which FS responses during the two exercise sessions were predicted to be not different from one another. More specifically, FS scores were significantly more positive during the MOD session compared to the equivalent time points of the HIT bout that corresponded to the high-intensity portions (i.e. 25%, 50%, 75%, and 100% of exercise duration; Table 4). Thus, participants perceived the high-intensity segments of the HIT bout to be significantly less pleasant than the corresponding time points of the MOD condition.

On the other hand, there were no significant differences between FS scores in the two conditions at the four low-intensity segments of the HIT bout (i.e. 10%, 35%, 60%, and 85% of exercise duration; Table 4). These findings suggest that, although the FS scores became more positive during the low-intensity segments of the HIT bout (to the point of not being significantly different from the corresponding MOD FS scores), these increases were not substantial enough to compensate for the decreases during the high-intensity segments, thus resulting in significantly lower overall pleasure scores in the HIT condition.

Considering the role of affective responses on exercise adherence (Williams et al., 2008), it is important to bear in mind the implications that the findings of the current study may have for public health. Although HIT exercise has been found to cause greater improvements in cardiorespiratory fitness (Helgerud et al., 2007), as well as increased fat oxidation (Talanian et al., 2007), the protocol used in the current study induced less pleasurable responses, which suggests that it may be too challenging to implement with inactive, obese individuals. Appropriately, Gibala and McGee (2008) pointed out the need to modify HIT protocols depending on the target population. It is conceivable that, in the current study, other combinations of intensities and durations of the low- and high-intensity segments might have elicited comparable affective responses to those found in the MOD bout. However, decreasing the intensity or increasing the duration of the active recovery portion would reduce the caloric expenditure and lengthen the total duration of the session (thus neutralizing the main argument for implementing HIT protocols in the public health arena). The total caloric expenditure and time-efficiency of a HIT bout are two factors that are of vital importance when implementing exercise regimens in obese populations, and thus cannot be overlooked. This presents a challenge for practitioners wanting to implement effective exercise programs and needs to be explored through future research.

When considering possible approaches for modifying the protocol of the current study, it is important for one to bear in mind that imposing even the slightest intensity above an individuals' preferred level will result in less pleasurable responses (Ekkekakis & Lind, 2006). On the other hand, if participants prefer an intensity that is well below VT it may not be sufficient to provide fitness improvements and successful weight management in a time-efficient manner. Interestingly, when previously sedentary, middle-aged women were allowed to exercise at their preferred intensity, they tended to self-select intensities around the VT (Lind, Joens-Matre, & Ekkekakis, 2005). Since exercising around the VT has been demonstrated to produce sufficient health benefits (Williams et al., 2008), and elicit pleasurable responses (Ekkekakis et al., 2004), allowing individuals to self-select a challenging intensity as well as an intensity that is comfortable for them, may be one approach to implementing high-intensity interval training for obese individuals.

Examination of FS changes during the HIT bout showed that scores tended to decrease during the high-intensity portions and gradually increase during the low-intensity portions (Figure 4). Analysis of FS scores during the MOD session demonstrated a gradual decline in FS throughout the exercise bout (Figure 4), which would be expected due to upward drift of heart rate, VO_2, and other physiological parameters over time. This finding is consistent with a recent study examining FS responses in low-active young women who did not know the duration of their exercise session (Welch, Hulley, & Beauchamp, in press). Participants in the present study were informed that the exercise duration of the two experimental conditions would range from 20 to 25 min, but were not provided with an exact duration in order to prevent them from knowing that the HIT bout was 5 min shorter.

Pre- to post-exercise analyses of FS during the two experimental exercise conditions showed a significant time main effect and a significant interaction but no trial main effect (Table 6). The time main effect was only present in the HIT trial, with all time points being significantly different from the immediate post-exercise scores. More specifically, pre-mask, post-mask, post cool-down, 10 min post cool-down, 20 min post cool-down, and 30 min post cool-down FS scores were all significantly more positive than the immediate post-exercise scores. This illustrates that participants felt the least pleasure immediately after exercise when compared to other non-exercise FS ratings. Furthermore, since no trial main effect was found, this means participants had similar FS responses immediately after exercise and during all other post-exercise FS assessments in both conditions. Such findings imply that although participants gave less positive ratings during the HIT bout, their post-exercise responses were comparable to those they had following the MOD bout.

Additionally, the participants' perceived exertion (RPE) during the two sessions was significantly different (Table 2), with higher RPE responses reported during the HIT condition. More specifically, RPE was significantly higher in the HIT bout than in the MOD bout during each of the high-intensity time point comparisons (i.e. 25%, 50%, 75%, and 100% of exercise duration). However, RPE scores from the initial active recovery portion of the HIT condition were significantly lower than those measured in the MOD condition. Interestingly, the RPE scores of the MOD session that corresponded to the 2nd, 3rd, and 4th active recovery portions of the HIT session (i.e. 35%, 60%, and 85% of exercise duration) were not significantly different from one another. These findings illustrate that the initial active recovery portion of the HIT session was perceived as requiring less exertion when compared to the first few minutes of the MOD session. Nonetheless, after participants had performed even one high-intensity portion of the HIT session, they perceived the subsequent active recovery portions of the HIT session to invoke a comparable level of exertion as the corresponding time points in the MOD session.

The overall RPE findings comparing the two conditions mirror the differences that were found in participants' affective responses. Both types of responses showed a lack of significant differences for the comparisons corresponding to the low-intensity time-points but significant differences for the comparisons corresponding to the high-intensity time-points of the HIT. This suggests that, initially, it may be necessary to use an even lower intensity during the recovery portion of HIT bouts than was used in the current study with inactive, obese individuals. Doing so may lead to further reductions in participants' exertion as well as more positive FS scores during the active recovery portions of this type of exercise. In turn, individuals may feel that the higher intensity portions are less challenging and potentially less unpleasant. However, as mentioned earlier, decreasing the intensity of the active recovery portions of the HIT complicates the issue of time-efficiency which is one of the purported reasons for implementing HIT bouts.

Brock and colleagues (in press) found participants' RPE from an acute bout of exercise to be significantly related to both weight regain and exercise behavior one year after a weight-loss intervention. More specifically, participants with higher RPE responses were found to report more weight regain and less physical activity at the one-year follow-up. Brock et al. (in press) stated that:

> although affective responses were not measured in this study, Williams *et al.*'s work suggests that affective responses to acute exercise add to the predictive capacity of long-term participation in physical activity, mostly independent of RPE and should therefore be considered two distinct components that deserve further exploration (p. 4).

As participants in the current study reported higher RPE levels during the HIT session, it is important to consider the long-term implications of both FS and RPE responses on exercise adherence.

Although no other studies have compared the affective responses of obese individuals during a continuous, moderate-intensity bout with a high-intensity interval bout, Coquart et al., (2008) compared perceived exertion responses between two conditions similar to those used in the current study. Their participants were obese individuals with and without type II diabetes. These researchers reported lower perceived exertion during the HIT condition than during the MOD condition. However, the intensity for the continuous, moderate-intensity session in that research was 100% of VT which may prevent inactive individuals from maintaining a physiological steady-state over a prolonged period of time. Additionally, a 2

(Condition) x 2 (Diabetic or Non-diabetic) ANOVA was run to compare mean differences in RPE. This analytic approach cannot reveal whether the RPE in the HIT session was lower as a result of responses during the active recovery portions or during the high-intensity portions. This analytic approach cannot reveal whether the RPE in the HIT session was lower as a result of responses during the active recovery portions or during the high-intensity portions. These limitations in the research of Coquart and colleagues (2008) prevent a direct comparison with the current study and further underscore the need for continued research in this area.

When examining the results of the current study, it is important to consider its potential limitations. First, the sample size for this study was relatively small, which limits the generalizability of the findings. Moreover, the sample was limited to middle-aged women who were inactive and obese but otherwise healthy. Thus, it would be inappropriate to extrapolate the findings to other populations (e.g. men, individuals with health conditions). However, it is necessary to consider the large number of individuals that initially showed interest in the study and the small number that completed all three sessions, as well as the fact that the sample size was sufficient in regards to finding significant results with adequate statistical power. Another limitation was the distribution of participants in the three obesity classes. There were 11 individuals in Class I, 11 in Class II, and only 2 in Class III. This distribution may suggest that the current results can be more appropriately applied to individuals within the first two classes of obesity.

The Feeling Scale responses and overall enjoyment ratings of the HIT session were lower than those for the MOD session, which may be partially attributed to the novel experience of performing an interval exercise bout. Since most exercise recommendations are centered around the idea of moderate-intensity, continuous bouts of exercise (ACSM, 2010), this is likely the type of exercise that may seem more familiar to participants in the current study. However, it should be borne in mind that all the women were prescreened to be inactive, so they did not have actual recent experiences with either format of exercise. Additionally, due to the fact that this study involved acute exercise bouts, one can only speculate as to whether or not the participants' affective responses to the HIT exercise may change as they become more accustomed to it over time. Thus, it would be desirable for future research to examine the possibility that obese individuals may develop increased tolerance for HIT over time and eventually respond more pleasurably.

Furthermore, previous research has found that sedentary individuals with lower tolerance for exercise intensity chose to terminate an exercise test earlier than those with a higher tolerance for exercise intensity regardless of their age, BMI, or VO_{2max} (Ekkekakis, Lind, Hall, & Petruzzello, 2007). Hence, it is important to consider the relationship between psychological parameters (i.e. affect and perceived exertion) and tolerance for exercise intensity. In the current study, participants' affective responses and RPE ratings to the exercise may have been substantially impacted by their tolerance for exercise intensity. Thus, future research should examine the interindividual differences in exercise intensity tolerance and the influence this may have on psychological factors during HIT.

Despite the fact that many challenges exist when implementing a study involving high-intensity exercise in an inactive and obese population, only one participant was unable to complete the HIT exercise session in the current study. This illustrates that the intensity and duration of the high and low periods used for the HIT sessions of the current study may be appropriate for use in the general population. However, it is important to consider that the study was performed in a laboratory environment with two researchers present, which may have led some participants to feel that they needed to keep going until the exercise was completed. Furthermore, due to the lower level of pleasure reported in the HIT trial, it is likely that individuals performing a similar workout on their own would be more apt to terminate the bout early due to the feeling of reduced pleasure.

Even though the age range of participants was fairly broad (19-54 years), one should not assume that these findings would be applicable across the entire age spectrum. In order to increase the generalizability of the present findings, it is necessary to conduct similar studies assessing these responses in a broader range of age groups. Additionally, since the present study involved an all-female sample, it is recommended that future research examine the affective responses of men to moderate, continuous and high-intensity interval exercise and compare them with those found here.

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APPENDIX A: DEMOGRAPHIC INFORMATION SHEET

Demographic Information

Name: ______________________________ **Gender**: Male ☐ Female ☐

Age:_________ Height:___________ Weight:___________

Birthday: ______/_______/_______ **Phone**: (515) -

E-mail address: ____

Par- Q & You

Yes **No**

☐ ☐ 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

☐ ☐ 2. Do you feel pain in your chest when you do physical activity?

☐ ☐ 3. In the past month, have you had chest pain when you were not doing physical activity?

☐ ☐ 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

☐ ☐ 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

☐ ☐ 6. Is your doctor currently prescribing drugs (for example, water pills) for you blood pressure or heart condition?

☐ ☐ 7. Do you know of any other reason why you should not do physical activity?

Brief Past Medical History

☐ ☐ 8. Have you ever been diagnosed with a medical condition that currently is under control (e.g., high blood pressure)? If yes, describe____

☐ ☐ 9. Were you prescribed any medication for this past medical diagnosis? If yes, describe________________________________

Risk Factors

1. <u>Smoking</u> **Yes** **No**

	Yes	No		
Do you smoke	☐	☐		
Cigarettes	☐	☐	How many per day? ____	How many years? ___
Cigar	☐	☐	How many per day? ____	How many years? ___
Pipe	☐	☐	How many times per day?__	How many years?____

HAVE YOU HAD A RECENT MEDICAL CHECK-UP?

It was explained to me that participation in bouts of vigorous exercise might be harmful to people with certain medical conditions. I hereby confirm that I have had a physical examination within the last 12 months, which showed that I am in perfect health. I also confirm that, to the best of my knowledge, I have no history of any cardiovascular, respiratory, musculoskeletal, or mental conditions. Finally, at this time, I am not suffering from any injuries or other ailments and I am under no medication.

_______________________________ _______________________________

(**Signature**) (**Date**)

Stages of Change Questionnaire

	True	False
1. I currently do not exercise	☐	☐
2. I intend to exercise in the next 6 months	☐	☐
3. I currently exercise regularly*	☐	☐
4. I have exercised regularly* for the past 6 months	☐	☐
5. I have exercised regularly* in the past for at least 3 months, but I am not doing so current	☐	☐

7-Day Physical Activity Recall Interview Questionnaire

Now we would like to know about your physical activity during the past 7 days. And also let me ask you about your sleep habits.

1. On the average, how many hours did you sleep each night during the last **5** weekday nights (Sunday through Thursday)? (Record to the nearest quarter-hour)

☐☐ ☐ Hours

2. On the average, how many hours did you sleep each night **last Friday and Saturday** nights?

□□ □ Hours

3. Now about your physical activities, let's first consider **moderate** activities. What activities did you do and how many total hours did you spend during the last **5** weekdays doing these moderate activities or others like them? Please tell me to the nearest half-hour.

□□ □ Hours

4. **Last Saturday and Sunday**, how many hours did you spend on **moderate** activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

□□ □ Hours

5. Now let's look at **hard** activities. What activities did you do and how many total hours did you spend during the last **5** weekdays doing these hard activities or others like them? Please tell me to the nearest half-hour.

□□ □ Hours

6. **Last Saturday and Sunday**, how many hours did you spend on **hard** activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

□□ □ Hours

7. Now let's look at **very hard** activities. What activities did you do and how many total hours did you spend during the last **5** weekdays doing these hard activities or others like them? Please tell me to the nearest half-hour.

☐☐ ☐ Hours

8. **Last Saturday and Sunday**, how many hours did you spend on **very hard** activities and what did you do? (Probe: Can you think of any other sport, job, or household activities that would fit into this category?)

☐☐ ☐ Hours

Scheduling

Your first trial is scheduled for: ________/__________/____________

Trial 2: __________/____________/_____________

Trial 3: __________/____________/_____________

Reminders for participants:

1. Do **NOT** smoke, drink caffeinated beverages, exercise or eat a heavy meal for 2 hours before testing time.
2. Come in **comfortable** clothes/shoes to exercise in.
3. Bring reading **glasses** if you need them for the surveys.

APPENDIX B: INSTRUMENTS

Borg's Scale of Perceived Exertion

HOW HARD DO YOU FEEL THE WORK IS?

6	
7	very, very light
8	
9	very light
10	
11	fairly light
12	
13	somewhat hard
14	
15	hard
16	
17	very hard
18	
19	very, very hard
20	

Feeling Scale

HOW DO YOU FEEL RIGHT NOW?

+5	**very good**
+4	
+3	**good**
+2	
+1	**fairly good**
0	**neutral**
-1	**fairly bad**
-2	
-3	**bad**
-4	
-5	**very bad**

Felt Arousal Scale

PLEASE RATE YOUR LEVEL OF AROUSAL.

6 High Arousal

5

4

3

2

1 Low Arousal

PACES

INSTRUCTIONS: Please rate how you feel at the moment about the physical activity you have been doing.

1.	I enjoy it	①②③④⑤⑥⑦	I hate it
2.	I feel bored	①②③④⑤⑥⑦	I feel interested
3.	I dislike it	①②③④⑤⑥⑦	I like it
4.	I find it pleasurable	①②③④⑤⑥⑦	I find it unpleasurable
5.	I am very absorbed in this activity	①②③④⑤⑥⑦	I am not at all absorbed in this activity
6.	It's no fun at all	①②③④⑤⑥⑦	It's a lot of fun
7.	I find it energizing	①②③④⑤⑥⑦	I find it tiring
8.	It makes me depressed	①②③④⑤⑥⑦	It makes me happy
9.	It's very pleasant	①②③④⑤⑥⑦	It's very unpleasant
10.	I feel good physically while doing it	①②③④⑤⑥⑦	I feel bad physically while doing it
11.	It's very invigorating	①②③④⑤⑥⑦	It's not at all invigorating
12.	I am very frustrated by it	①②③④⑤⑥⑦	I am not at all frustrated by it
13.	It's very gratifying	①②③④⑤⑥⑦	It's not at all gratifying
14.	It's very exhilarating	①②③④⑤⑥⑦	It's not at all exhilarating
15.	It's not at all stimulating	①②③④⑤⑥⑦	It's very stimulating
16.	It gives me a strong sense of accomplishment	①②③④⑤⑥⑦	It does not give me any sense of accomplishment
17.	It's very refreshing	①②③④⑤⑥⑦	It's not at all refreshing
18.	I felt as though I would rather be doing something else	①②③④⑤⑥⑦	I felt as though there was nothing else I would rather be doing

Scoring--Reverse score: Items 1, 4, 5, 7, 9, 10, 11, 13, 14, 16, 17
(i.e., 1=7, 2=6, 3=5, 4=4, 5=3, 6=2, 7=1).

APPENDIX C: INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Investigation of Physiological and Psychological Responses to Exercise

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**Research assistant who will conduct the study and obtain informed consent

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to examine physiological and psychological responses to exercise on a cycle ergometer. You are being invited to participate in this study because we are investigating specific physiological and psychological responses of females between the ages of 18 and 54.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, your participation will last for the duration of 3 separate visits to the exercise psychology laboratory (164M Forker Building on the ISU campus). During the **first visit**, you will be familiarized with the instruments and equipment used in the data collection process and will perform a graded (incremental) exercise bout on a recumbent cycle ergometer. This exercise session determines the ability of your body to take oxygen from the air, deliver it to your working muscles and utilize the oxygen in the muscle. The pedal resistance of the cycle ergometer will be gradually increased until you choose to discontinue the exercise bout. You will be able to terminate the session yourself when you feel that you have reached your limit. This exercise session is expected to last between 5 and 15 minutes in addition to warm-up and cool-down. Before the session, the researchers will also attach a breathing mask on your face, so that they can collect and analyze the gases that you expire and, thus, determine how much oxygen you are using. A heart rate monitor will be placed around your chest to monitor heart function during the exercise session. There will be a 3-minute warm-up before the exercise bout and a 5-minute cool-down following the exercise bout. Upon completion of the exercise session, you will rest comfortably for 30 minutes. During the exercise bouts, the researchers will ask you to indicate how you feel on some simple ratings scales. All the visits are expected to last approximately 60 to 90 minutes. During the second and third visits, you will perform an exercise bout lasting 20-30 minutes. There are two possible types of exercise bouts that you may be asked to complete. One possibility would involve cycling at a continuous, moderate-intensity while the other would involve alternating between high and low intensities.

You will also be asked to fill out questionnaires during the time you are in the laboratory. You may skip any question that you do not wish to answer or that makes you feel uncomfortable.

RISKS

While participating in this study you may experience the following risks: Participating in vigorous exercise may carry potential dangers, such as cardiovascular problems or musculoskeletal injuries. Although it is not possible to predict all such occurrences, the researchers try to minimize the risk. Other possible adverse effects include: (a) Muscle soreness or fatigue during or following the exercise sessions. These effects should not last more than a couple of days. You have the right to request that another exercise session not be scheduled until these symptoms have passed, and (b) Discomfort associated with wearing the face mask that will be used for the collection of expired gases. You will be able to try this mask on to see whether you feel comfortable wearing it. The researchers will assist you in adjusting the mask so that it is as comfortable as possible, but you have the right to withdraw your consent if you feel discomfort or resistance in your breathing. Please note that all materials that you will come in contact with (including the face mask) will be either single-use or thoroughly washed and disinfected.

BENEFITS

If you decide to participate in this study you will have the opportunity to receive a free fitness assessment and specific, personalized physical activity recommendations based on your fitness assessment. It is also hoped that the information gained in this study will benefit society by providing valuable information on the types and amounts of physical activity that are likely to increase people's motivation to remain active over the long haul.

COSTS AND COMPENSATION

You will not have any costs from participating in this study. You will not be compensated for participating in this study.

PARTICIPANT RIGHTS

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

RESEARCH INJURY

Emergency treatment of any injuries that may occur as a direct result of participation in this research is available at the Iowa State University Thomas B. Thielen Student Health Center, and/or referred to Mary Greeley Medical Center or another physician or medical facility at the location of the research activity. Compensation for any injuries will be paid if it is determined under the Iowa Tort Claims Act, Chapter 669 Iowa Code. Claims for compensation should be submitted on approved forms to the State Appeals Board and are available from the Iowa State University Office of Risk Management and Insurance.

CONFIDENTIALITY

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies**,** auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, your name and other identifying information will be permanently erased once the collected data have been tabulated and entered in a computer for statistical analysis. Thus, there will be no traceable connection between your name and your data. Until the data are tabulated, your records will be kept in a room that will be locked at all times and only the researchers will have access to it. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS

You are encouraged to ask questions at any time during this study. For further information about the study contact Ms. Emily Decker (164M Forker Building, 515-294-5418, exercise@iastate.edu) or Dr. Amy Welch (251 Forker Building, 515-294-8042, amywelch@iastate.edu). If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office of Research Assurances, Iowa State University, Ames, Iowa 50011.

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PARTICIPANT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study. If this form was sent to you via e-mail, please print a copy of all pages to keep for your files.

Participant's Name (printed) ____

______________________________________ ______________________

(Participant's Signature) (Date)

INVESTIGATOR STATEMENT

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

(Signature of Person Obtaining Informed Consent)	(Date)